Claims

1. A device for measuring a glucose level in a living body, said device comprising

a sensor arrangement (5, 6) to be applied to a surface of the body,

processing circuitry (31 - 33, 37, 38) for measuring a response of the sensor arrangement and deriving the glucose level therefrom, and

at least a first and a second temperature sensor (15, 22) wherein a signal of the first temperature sensor depends in different manner on a skin temperature of the body and on an environmental temperature than a signal of the second sensor.

2. The device of claim 1 wherein the first temperature sensor (15) is closer to said sensor arrangement (5, 6) than the second temperature sensor (22).

3. The device of any of the preceding claims further comprising a housing (1) having a first side and a second side, wherein said sensor arrangement (5, 6) is arranged on said first side and wherein said first temperature sensor (15) is arranged at said first side and said second temperature sensor (22) at said second side.

4. The device of any of the preceding claims wherein said first temperature sensor (15) is in thermal contact with said sensor arrangement.

5. The device of any of the preceding claims further comprising an assembly (19) of electronic circuits wherein said second temperature sensor (22) is in thermal contact with said assembly (19).

6. A device (100, 102), in particular of any of the preceding claims, for measuring a glucose level in a living body, said device comprising

a sensor arrangement (5, 6) to be applied to a surface of the body,

processing circuitry (31 - 33, 37, 38) for measuring a response of the sensor arrangement and deriv-

ing the glucose level therefrom, wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level g from

$$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M),$$

where F is a function depending on $N \geq 1$ measured input values $s_1 \ldots s_N$, wherein the function F has M+1 calibration parameters $a_0 \ldots a_M$ with $M \geq 0$, and

calibration means (38, 102) for storing a series of input values $s_j(t'_i)$ recorded at times t'_i in a given calibration phase and a series of reference values $g(t_i)$ measured at times t_i in the calibration phase and deriving at least part of the parameters a_i therefrom by comparing values obtained from the input values by function F against the reference values or against values derived from the reference values.

7. The device of claim 6 wherein said calibration means (102) is adapted for calculating at least part of said parameters a_i by minimizing a deviation of the values

$$F(t'_i) = F(s_1(t'_i) \ldots s_N(t'_i), a_0 \ldots a_M)$$

from a prediction S of the glucose level at the times t'_i, wherein said prediction is derived from the reference values $g(t_i)$.

8. The device of claim 7 wherein said calibration means (102) is adapted to minimize the deviations

$$d_i = \begin{cases} F(t'_i) - S_{max}(t'_i) \text{ if } F(t'_i) > S_{max}(t'_i) \\ S_{max}(t'_i) - F(t'_i) \text{ if } F(t'_i) < S_{min}(t'_i) \\ 0 \text{ otherwise} \end{cases}$$

wherein $S_{min}(t'_i)$ and $S_{max}(t'_i)$ are minimum and maximum values of the glucose level at time t'_i.

9. The device of claim 8 wherein said calibration means (102) are adapted to minimize a sum of absolute values of the values d_i.

10. The device of any of the claims 6 to 9, wherein said calibration means (102) is adapted for

detecting the times $\tau_1 \ldots \tau_P$ when a shift of said device in respect to said body occurs during said calibration phase, and,

for comparing values obtained by function F against the reference values $g(t_i)$ or against values derived from the reference values $g(t_i)$, replacing at least parameter a_0 of said parameters by

$$\sum_{i=0}^{P} a_{0i} \cdot b_i(t)$$

with $b_i(t)$ being 1 for $\tau_i < t < \tau_{i+1}$ and 0 otherwise, wherein τ_0 and τ_{P+1} are the start and end times of the calibration phase.

11. The device of any of the claims 6 to 10 further comprising a recalibration means (38) for carrying out a recalibration step during which one of said parameters is varied to find an optimum agreement between the glucose level calculated from the function F and a glucose level from a reference measurement.

12. A device (100, 102), in particular of any of the preceding claims, for measuring a glucose level in a living body, said device comprising

a sensor arrangement (5, 6) to be applied to a surface of the body,

processing circuitry (31 - 33, 37, 38) for measuring a response of the sensor arrangement and deriving the glucose level therefrom, wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level from

$$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M),$$

where g is the glucose level and F is a function depending on $N \geq 1$ measured input values $s_1 \ldots s_N$, wherein the function F has M+1 calibration parameters $a_0 \ldots a_M$ with $M \geq 0$, and

a shift correction (38) adapted for detecting a displacement of said device in respect to said body,

determining an effect of the shift on the measured glucose level and correcting the measured glucose level after the shift to compensate for the determined effect.

13. The device of claim 12 wherein said shift correction (38) is adapted for detecting the displacement by monitoring for a shift in a signal value v derived from at least one of the input values s_i.

14. The device of any of the claims 12 or 13 wherein said shift correction (38) is adapted to determine the effect of the shift on the measured glucose level by comparing an extrapolation ($v_{ext}(t)$) of signal values measured prior to the displacement with at least one signal value measured after the displacement.

15. The device of claim 14 wherein said shift correction (38) is adapted to determine the effect of the shift on the measured glucose level by calculating a difference between or a ratio of the extrapolation ($v_{ext}(t)$) and at the least one signal value measured after the displacement.

16. A device, in particular of any of the preceding claims, for measuring a glucose level in a living body, comprising

a detector comprising processing circuitry (31 - 33, 37, 38) for measuring the glucose level g(t) repetitively,

a predictor for predicting a glucose level, wherein said predictor is designed for calculating a prediction of the glucose level from an estimate of the current value of the glucose level g(t) as well as its derivative $\dot{g}(t)$, taking into account that the prediction must fulfil the conditions

$$\dot{g} \geq -\dot{g}_{decr} \text{ and } \ddot{g} \geq -\ddot{g}^{-} \text{ and/or}$$

$$\dot{g} \leq \dot{g}_{incr} \text{ and } \ddot{g} \leq \ddot{g}^{+}$$

17. The device of claim 16 wherein said predictor is designed for calculating a worst-case time until the glucose level reaches a lower or upper limit and

to issue an alert if the worst-case time is less than a given threshold time.

18. The device of any of the preceding claims wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level g from

$$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M),$$

where g is the glucose level and F is a function depending on $N \geq 1$ measured input values $s_1, s_2, \ldots s_N$, wherein the function F has M+1 calibration parameters $a_0, a_1, \ldots a_M$ with $M \geq 0$.

19. The device of claim 18 wherein parameter a_0 is an additive or multiplicative parameter in function F.

20. The device of any of the claims 18 or 19 wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level g from $g = a_0 + a_1 \cdot s_1 + a_2 \cdot s_2 + \ldots a_N \cdot s_N$.

21. The device of any of the claims 18 to 19 wherein at least one of said measured input values is indicative of a response of the sensor arrangement (5, 6).

22. The device of any of the claims 18 to 21 further comprising

a signal source (31) for applying a frequency sweep to a signal path (34), wherein said sensor arrangement (5, 6) is connected to said signal path, and

a detector (37) for determining a characteristic frequency (f0) and/or amplitude (A0) at which a signal in said signal path (34) becomes minimum and/or a phase shift in said signal path goes through zero,

wherein said measured input values $s_1, s_2, \ldots s_N$ comprise a value indicative of said characteristic frequency (f0) and/or amplitude (A0).

23. The device of any of the claims 18 to 22 further comprising at least a first and a second temperature sensor (15, 22) wherein a signal of the first temperature sensor (15) depends in different manner on a skin temperature (Ts) of the body and on an environmental

temperature (Te) than a signal of the second sensor (22), wherein said measured input values s_1, s_2, ... s_N comprise signals (T1, T2) from said first and said second temperature sensors.

24. The device of any of the preceding claims comprising a holder (52) for affixing it to the body.

25. The device of any of the preceding claims wherein said sensor arrangement (5, 6) comprises an electrode arrangement with at least one electrode (5, 6), in particular at least two electrodes, and said processing circuitry comprises at least one signal source (31) for applying a signal to said electrode arrangement and a signal detector (37) for detecting a response from said electrode arrangement to said signal.

26. A method for measuring a glucose level in a living body comprising the steps of

applying a sensor arrangement (5, 6) to a surface of the body,

measuring a response of the sensor arrangement and deriving at least one first value (A0, f0) therefrom,

measuring at least a second and a third value (T1, T2) with a first and a second temperature sensor (15, 22), wherein the second value (T1) depends in different manner on a skin temperature of the body and on an environmental temperature than the third value (T2),

calculating from said first, second and third values (A0, f0; T1; T2) said glucose level using calibration parameters (a_0 ... a_M).

27. A method for operating a device for measuring a glucose level in a living body, said device comprising a sensor arrangement (5, 6) to be applied to a surface of the body, and processing circuitry (31 - 33, 37, 38) for measuring a response of the sensor arrangement and deriving the glucose level therefrom, wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level g from

$$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M),$$

where F is a function depending on $N \geq 1$ measured input values $s_1 \ldots s_N$, wherein the function F has M+1 calibration parameters $a_1, \ldots a_M$ with $M \geq 0$, wherein said method comprises the steps of:

detecting a displacement of the device in respect to the body,

determine an effect of the shift on the measured glucose level, and

correcting the measured glucose levels after the shift to compensate for the determined effect.

28. The method of claim 27 wherein the displacement is detected by monitoring for a shift in a signal value (v) derived from at least one of the input values s_i.

29. The method of any of the claims 27 or 28, wherein the effect of the shift on the measured glucose level is determined by comparing an extrapolation ($v_{ext}(t)$) of signal values ($v(t)$) measured prior to the displacement with at least one signal value ($v(t)$) measured after the displacement.

30. The method of claim 29, wherein the effect of the shift on the measured glucose level is determined by calculating a difference between or a ratio of the extrapolation ($v_{ext}(t)$) and the at least one signal value measured after the displacement.

31. A method for calibrating a device for measuring a glucose level in a living body, said device comprising a sensor arrangement (5, 6) to be applied to a surface of the body and processing circuitry (31 - 33, 37, 38) for measuring a response of the sensor arrangement and deriving the glucose level therefrom, wherein said processing circuitry (31 - 33, 37, 38) is adapted for calculating the glucose level g from

$$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M),$$

where F is a function depending on $N \geq 1$ measured input values $s_1 \ldots s_N$, wherein the function F has M+1 calibration parameters $a_1, \ldots a_M$ with $M \geq 0$, and

said method comprising the step deriving at least part of said parameters a_i from a series of input values $s_j(t'_i)$ recorded at times t'_i in a given calibration phase and a series of reference values $g(t_i)$ measured at times t_i in the calibration phase by comparing values obtained by function F against the reference values or against values derived from the reference values.

32. The method of claim 31 wherein at least part of said parameters a_i is calculated by minimizing a deviation of the values

$$F(t'_i) = F(s_1(t'_i) \ldots s_N(t'_i), a_0 \ldots a_M)$$

from a prediction S at the times t'_i, wherein said prediction is derived from the reference values $g(t_i)$.

33. The method of any of the claims 31 or 32 comprising the steps of

detecting the times $\tau_1 \ldots \tau_P$ when a shift of said device in respect to said body occurs during said calibration phase, and,

for comparing values obtained by function F against the reference values $g(t_i)$ or against values derived from the reference values $g(t_i)$, replacing at least one parameter a_0 by

$$\sum_{i=0}^{P} a_{0i} \cdot b_i(t),$$

with $b_i(t)$ being 1 for $\tau_i < t < \tau_{i+1}$, wherein τ_0 and τ_{P+1} are the start and end times of the calibration phase.

34. The method of any of the claims 31 to 33 wherein, during said calibration phase, an environment temperature is varied by at least 5 °C, in particular by at least 10 °C, and wherein at least one, in particular two, of said input values is/are an input temperature (T1, T2) the value of which depends on the environment temperature, and in particular wherein two input tempera-

tures T1 and T2 are measured, wherein the temperature T1 depends in different manner on a skin temperature of the body and on an environmental temperature than the temperature T2.

35. The method of any of the claims 31 to 34 wherein, during said calibration phase, the glucose level is varied by at least 100 mg/dl.

36. The method of any of the claims 31 to 35 further comprising a recalibration step during which one of said parameters is varied to find an optimum agreement between the glucose level calculated from the function F and a glucose level from a reference measurement.

37. A method for predicting the glucose level in a living body comprising the steps of

measuring the glucose level g(t) repetitively,

predicting a future glucose level from an estimate of the current value of the glucose level g(t) as well as its derivative $\dot{g}(t)$, taking into account that the prediction must fulfil the conditions

$\dot{g} \geq -\dot{g}_{decr}$ and $\ddot{g} \geq -\ddot{g}^{-}$ and/or

$\dot{g} \leq \dot{g}_{incr}$ and $\ddot{g} \leq \ddot{g}^{+}$.

38. The method of any of the claims 26 to 37 wherein said glucose level g is determined by

$g = F(s_1, s_2, \ldots s_N, a_0, a_1, \ldots a_M)$,

where F is a function depending on $N \geq 1$ measured input values $s_1, s_2, \ldots s_N$, wherein the function F has M+1 calibration parameters $a_0, a_1, \ldots a_M$.

39. The method of claim 38 wherein parameter a_0 is an additive or multiplicative parameter in function F.

40. The method of claim 39 wherein the glucose level g is calculated from $g = a_0 + a_1 \cdot s_1 + a_2 \cdot s_2 + \ldots a_N \cdot s_N$.

41. The method of any of the claims 27 to 40 wherein said sensor arrangement (5, 6) comprises an electrode arrangement with at least one electrode (5, 6), in

particular at least two electrodes, wherein a signal is applied to said electrode arrangement and a response from said electrode arrangement to said signal is measured.